Lat 39.88581 Lon -121.18592

Forest Health Protection
Pacific Southwest Region

Date: February 23, 2011
File Code: 3420

To: District Ranger, Mt. Hough Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and diseases in the Bucks Lake Fuels Reduction and Roadside Hazard Tree Removal Project (FHP Report NE11-06)

At the request of Alex Yiu, Assistant Silviculturist, Mt. Hough Ranger District, I visited the Bucks Lake Project on September 19, 2010. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss treatment alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as drought, fire, insects and diseases. Alex accompanied me in the field.

Site information

The Bucks Lake Project is located around Bucks Lake at elevations ranging between 5000 and 6000 feet (39° 53.1486"N and 121° 11.1552"W) with annual precipitation between 70 and 90 inches. Most of the area lies within the 70 to 80 inch precipitation zone with greater amounts falling along the southern edge of the project area. Forest cover is comprised of dense variations of Sierra Nevada mixed conifer with white fir (*Abies concolor*) and red fir (*Abies magnifica*) being the main overstory trees in most stands. Sugar pine (*Pinus lambertiana*) is a minor overstory component in many of these true fir dominated stands. Douglas-fir (*Psuedotsuga menziesii*), Jeffrey pine (*Pinus jeffreyi*), ponderosa pine (*Pinus ponderosa*), incense cedar

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(*Calocedrus decurrens*) and lodgepole pine (*Pinus contorta var. murrayana*) are present in many stands but at lower levels; with the exception of a few Douglas-fir dominated mixed conifer stands and Jeffrey/ponderosa pine dominated plantations. Management objectives for the Bucks Lake Project are to create defensible fuel profile zones (DFPZs) along road corridors by removing surface and ladder fuels and reducing stocking levels. Some areas will be thinned beyond the DFPZ boundaries to further reduce stocking levels and improve growing conditions for residual trees. Hazard tree abatement will also be incorporated along all roads and within recreation sites including summer home tracts.

Forest insect and disease conditions

General project area

Insect and/or disease caused tree mortality is occurring at low levels within the Bucks Lake area. However, there has been a recent increase in true fir mortality attributable to the combined effects of drought, heterobasidion root disease (*Heterobasidion occidentalis*, formerly referred to as S-type annosus root disease), high stand density and attacks by the fir engraver beetle (*Scolytus ventralis*). Forest Health Protection (FHP) aerial detection surveys (ADS) mapped 6,135 acres of forested land with various levels of tree mortality (nearly all red and white fir) within the project area in 2010; about 1/3 more than the combined number of acres mapped the previous 5 years (2005-2009).

Dwarf mistletoe (*Arceuthobium abietinum*) infections combined with cytospora cankers (*Cytospora abietis*) are contributing to a decline in true fir health in some areas by causing branch mortality.

White pine blister rust (*Cronartium ribicola*) is causing branch mortality and top-kill in some sugar pine.

Regeneration of pine species is lacking in most stands due to shading and competition from true fir (mostly white fir).

Bucklin Road stand (T23N, R7E, SW ¼ Sec. 3 and SE ¼ Sec. 4, [Units 58 and 93])

This stand contains many old growth true firs and fire-scarred sugar pine with a dense understory of white fir. Duff and litter accumulation is deep, especially around the bases of large trees (Figure 1).

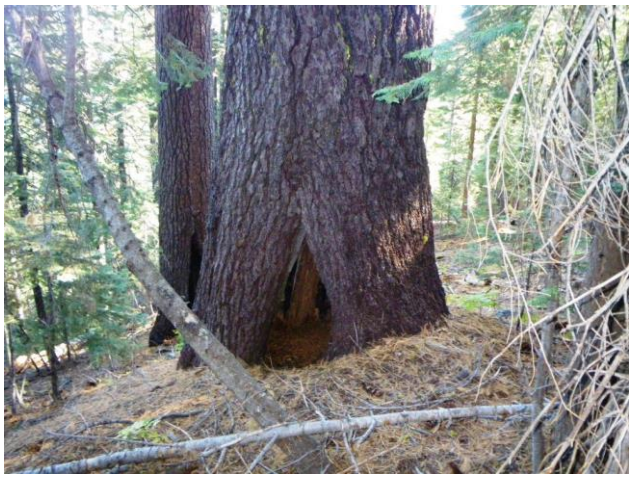

Figure 1. Old growth fire-scarred sugar pine with deep duff and litter layer.

Heterobasidion root disease centers are located within the stand as indicated by the presence of conks in old true fir stumps, stunted leader growth of infected

Figure 2. Base of recently killed red fir showing frass and boring dust from fir engraver and ambrosia beetle attacks.

trees and recent top-kill and whole tree mortality caused by the fir engraver beetle (Figure 2).

White pine blister rust is causing branch flagging and top-kill on a few sugar pine.

Bucks Lake Road stand (south end of lake) (T23N, R7E, SW ¼ Sec. 2, [Unit 110])

White fir dwarf mistletoe (*Arceuthobium abietinum f. sp. concoloris*) is present throughout the stand in both overstory and understory white fir. Infection levels are particularly high on the drier south facing slope where they are contributing to branch mortality and declining tree health (Figure 3).

Heterobasidion root disease centers are likely present on this site based on the declining crown condition of many small groups of white fir. However, no effort was made to confirm heterobasidion due to time constraints and a lack of available stumps for inspection.

Whole tree mortality caused by the fir engraver beetle and top-kill caused by the fir engraver and/or other engraver beetles (*Scolytus* spp.) is occurring on the south facing slope of this stand.

Figure 3. Dwarf mistletoe, and possibly heterobasidion root disease, infected white fir with older and more recent top-kill.

Jeffrey pine plantation (Bucks Lake Road east of lake) (T24N, R8E, SE ¼ Sec. 31, [Unit 83])

This primarily Jeffrey pine plantation is overstocked with pole and small sawlog sized trees. Several trees suffered snow breakage over the past winter but no significant pine engraver beetle (*Ips* spp.) activity was detected in downed boles or in adjacent live trees (Figure 4).

Figure 4. Dense Jeffrey pine plantation with recent snow breakage.

Stand conditions and mortality related to recent and future climate trends

Evidence exists, in the form of fire scars on large diameter pine (Figure 1), of a relatively frequent historic fire regime within portions of the Bucks Lake area. This suggests that pines once made up a larger percentage of most stands and that fire played an important ecological role in maintaining a more open forested landscape. Fire exclusion in the area has now facilitated an increase in shade tolerant true fir at the expense of shade intolerant pine species.

Most stands within the Bucks Lake Project are in an overstocked condition with scattered pockets of heterobasidion root disease infected true fir (Douglas-fir is mostly resistant to *H. occidentale* in the Sierra Nevada range). These conditions combined with the recent extended dry period (2007-2009) are resulting in elevated levels of fir engraver beetle caused mortality. Pine species in this area, although not currently under attack, are also susceptible to bark beetle attacks and subsequent tree mortality due to generally overstocked stand conditions and excessive competition from true fir. Mapping by ADS over the past 10 years within and adjacent to the Bucks Lake Project reveals many areas where bark beetle caused tree mortality has occurred at elevated levels (Figure 5).

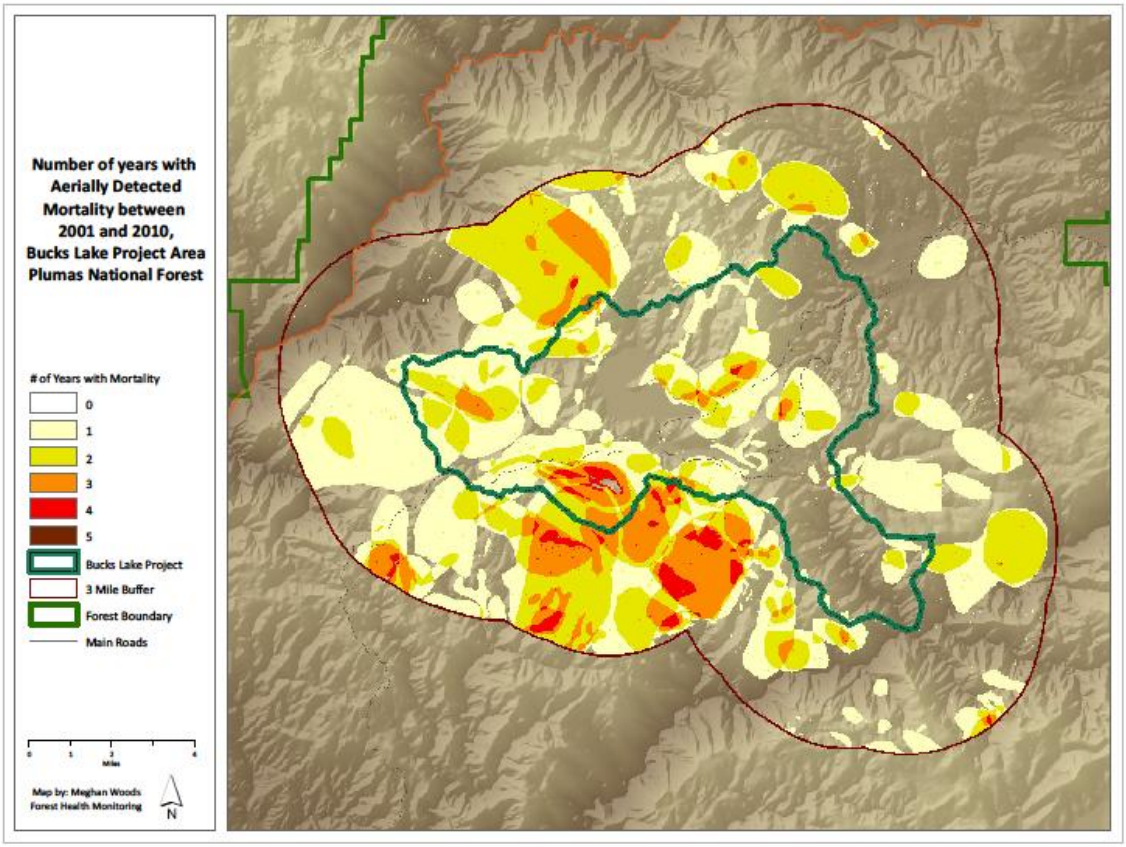

Figure 5. Areas and number of years with mapped tree mortality within and adjacent to the Bucks Lake Project (mapped centered on Bucks Lake).

Figure 5 also depicts many areas where no mortality was mapped during the past 10 years. This does not necessarily indicate the existence of healthy forest conditions. Many stands within this "mortality free" zone are at a high risk to bark beetle and/or root disease caused tree mortality due to overstocked conditions and could experience unacceptable levels of tree mortality in the future.

Elevated levels of tree mortality in this area, as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions resulting in higher levels of bark beetle caused tree mortality. Table 1 highlights the relationship between drought and tree mortality for the Bucks Lake Project area using ADS data and the Palmer Hydrologic Drought Index.

Table 1. Acres, dead trees per acre, total dead trees and Palmer Hydrologic Drought Index (PHDI) by year within and adjacent to the Bucks Lake Project as estimated from annual FHP aerial detection surveys.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI*
2010	6,135	1.96	12,052	0.14
2009	2,704	1.38	3,741	-2.52
2008	45	2.33	106	-2.71
2007	937	0.55	514	-2.64
2006	20	2.09	41	2.71
2005	342	0.61	208	0.37
2004	23,329	1.05	24,405	-1.22
2003	33,725	2.14	72,020	-0.54
2002	37,474	2.29	85,680	-2.12
2001	985	5.32	5,243	-1.58

*Palmer Hydrologic Drought Index for the Sierra Cascade Climate Division obtained from NOAA. PHDI values ranging from -1.00 to -1.99 are considered mild drought conditions, -2.00 to -2.99 are moderate drought conditions and -3.00 to -3.99 are severe drought conditions.

Predicted climate change is likely to impact trees growing in this area over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (C. Mallek and H. Safford 2010). The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially disease infected true fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Considerations for thinning treatments

Prescriptions that meet the requirements of a DFPZ should also be consistent with past direction from the Regional Forester to thin to "ensure that density does not exceed an upper limit (for example: 90% of normal basal area, or 60% of maximum stand density index)" and to "design

thinnings to ensure that this level will not be reached again for at least 20 years after thinning." (Regional Forester letter, "Conifer Forest Density Management for Multiple Objectives", July 14, 2004). Reducing stocking levels to this range should effectively reduce inter-tree competition for limited water and nutrients and reduce the risk of insect and disease caused mortality.

The Bucks Lake area is within a very high precipitation zone and some stands contain a high percentage of red fir. Red fir dominated stands do not typically experience high levels of density related mortality in the Sierra Nevada. However, high stand density is certainly a stress factor and contributes to self-thinning and localized bark beetle activity but most mortality of red fir in these areas will be due to a complex of high stand density, root disease, dwarf mistletoe, cytospora canker and periodic drought. Any thinning treatments in these areas should focus on reducing the number of moderate to severely diseased trees in addition to reducing fuels and stand density.

Some stands on south facing and lower elevation slopes within the Bucks Lake area contain higher percentages of pine species and/or Douglas-fir with a high proportion of white fir in the understory. Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the existing white fir basal area, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire).

Radial thinning around large diameter old growth pines, especially the large diameter sugar pines that are scattered throughout the project area, should also be considered to further increase their growth and vigor. Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (FHP unpublished data).

Special consideration needs to be given to sugar pine in the Bucks Lake Project. Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. If any rust resistant sugar pines are located within the project area, they should have all competing vegetation and fuels removed from their immediate area, including the removal of larger competing trees reducing crown exposure and facilitating squirrel access to cones. In addition, planting openings created by any group selection harvest with rust resistant stock would help insure this species persists in the area.

A few areas consist of white fir dominated stands that likely established over the last 100+ years within historically fire maintained brush fields. These stands are characterized by a very high percentage of white fir, the presence of old dead brush "skeletons" (e.g. *Arctostaphylos* spp. and *Ceanothus* spp.) on the forest floor and a lack of evidence of the historic presence of pine species (stumps, downed logs, snags, etc). These stands often contain scattered pockets of root disease and dwarf mistletoe infections and are in generally poor health. These areas will benefit by focusing management on the retention and enhancement of tree species other than white fir. This

can be accomplished by thinning competing white fir away from any pine, incense cedar or Douglas-fir (if they exist) and removing white fir from *H. occidentale* and dwarf mistletoe centers to create small openings that can be planted to non-host species. Where non-host species do not exist and evidence of root disease is lacking, white fir should be thinned to the desired stocking by removing the slow-growing trees or clumps of trees. Slow-growing fir trees are usually those with short leader growth (rounded tops). A short leader can be caused by inter-tree competition, soil compaction, mechanical or weather-caused injury, and/or insect and disease activity (e.g. fir engraver, *H. occidentale*, dwarf mistletoe, etc.). Since it is impossible to identify every fir tree that is infected with *H. occidentale*, the combination of the above treatments will result in leaving some trees with non-symptomatic *H. occidentale* infections. This will be partially mitigated by the reduction in stand density, which should improve individual tree health and vigor. Since *H. occidentale* is a disease that primarily infects the heartwood of true fir, low level infections on non-symptomatic trees will generally only be lethal under severe drought conditions.

Dense plantations of even-aged, sawlog sized Jeffrey and ponderosa pine are especially susceptible to large group killing by bark beetles during extended periods of below normal precipitation. Based the observed high stand density, it appears the plantation along Bucks Lake Road is well above the bark beetle limiting SDI of 365 for ponderosa pine. SDI 365 is considered the upper management zone above which bark beetle outbreaks are likely to occur (Oliver 1995). This recommended stocking level is also applicable to Jeffrey pine stands and mixed Jeffrey and ponderosa pine (eastside pine) stands in northeastern California.

The best strategy to reduce the risk of bark beetle caused mortality is to reduce stand density through thinning. Thinning to reduce SDI to 230 or below will increase the health and vigor of residual pines and put plantations at or below the defined threshold for the zone of imminent bark beetle caused mortality. Within this zone, endemic populations kill a few trees but net growth is still positive (Oliver 1995). In addition, thinning can also change the microclimate of the stand, creating a less favorable environment for bark beetle pheromone communication. Opening up the canopy creates convection currents and air turbulence through increases in soil temperature as well as increasing wind speed (Bartos and Amman 1989, Amman and Logan 1998). This prevents bark beetle pheromone plumes from concentrating under the canopy and remaining in close proximity to individual trees or groups of trees.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, should benefit by having the stocking around them reduced to lower levels. Areas of pure or nearly pure ponderosa and Jeffrey pine would also benefit from lower stocking levels as well as an increase in species diversity. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. This type of approach would also be consistent with the Region 5 Leadership Intent for Ecological Restoration.

When implementing thinning projects, retaining more drought tolerant species such as sugar pine, ponderosa pine, Jeffrey pine, Douglas-fir and incense cedar over true fir will increase species diversity and make stands more resilient. In addition, when selecting trees for removal,

preference should be given to trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. However, white pine blister rust infected sugar pine could be retained, especially if the infections do not appear lethal to the tree (such as infections causing only branch flagging). If thinning treatments fail to address obvious heterobasidion root disease centers, significant mortality of infected trees may occur during extended drought periods, regardless of residual stocking levels. This could lead to increased numbers of future hazard trees in roadside and recreation areas, including summer home tracts.

It is recommended that a registered borate compound be applied to all freshly cut stumps >14" dbh to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *Heterobasidion occidentalis* (formerly 'P' and 'S'-type annosus root disease) within roadside treatment units. Treating in these units may reduce the number of future root diseased trees that could pose a hazard to the public. Since hazard tree considerations are not as critical for treatments units away from roads, stump treatments may not be necessary. *H. irregulare* is not typically a problem in pines on the west side of the Plumas National Forest and treatment of fir stumps may not be beneficial if stands already have a high level of *H. occidentale*. In these units, treatment of fir stumps can be reserved for areas that appear to be free of root disease (see root disease and crown characteristic discussion under hazard tree section). Recreation sites, which should include Forest Service summer home tracts, require the treatment of all stumps greater than 3" in diameter (FSM R5 Supplement 2300-92-1 modified by FSH R5 Supplement 3409.11-2010-1). Care also needs to be taken to minimize injury to residual true fir in all thinning and fuels reduction operations as fresh wounds provide additional entry courts for *H. occidentale*.

Considerations for prescribed fire

The fire scars on old sugar pine (see Figure 1) indicate that fire burned this stand numerous times prior to modern-day fire suppression and played an important role in local ecosystem processes. However, returning fire to the system and using it as a maintenance tool may result in unacceptable levels of tree injury and mortality.

If prescribed fire is used as a follow-up treatment to stand thinning, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature Jeffrey, ponderosa and especially sugar pines are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is highly recommended.

White fir and red fir occurring in nearly pure stands tend to have very high levels of course woody debris on the forest floor as a result of downed logs from self thinning, the continual shedding of branches and the remaining stems from old stands of brush that have been overtopped and killed by dense fir canopies. These types of stands produce tremendous amounts of heat on the ground surface and often cause severe injuries to the boles and crowns of standing

trees, especially to smaller diameter trees (Figure 6). If high post-burn mortality levels in true fir stands, resulting in openings and possibly additional heavy fuel loading, is not an acceptable condition, than fuel treatments such as hand or tractor piling should be considered prior to or in place of prescribed fire. This is especially important in roadside units or in stands adjacent to recreation areas and summer home tracts due to the potential for some fire-injured trees to deteriorate into an unstable and hazardous condition (see Appendix A – Hazard Tree Alert).

Figure 6. Dead and dying fire-injured white fir trees in 10+ year old prescribed burn, Tahoe NF.

Potential for hazard trees

Roadside and recreation areas around Bucks Lake invite the public to stop, take pictures, hike, picnic and spend extra time within forested areas. This brings up the issue of hazard trees, especially with the presence of *Heterobasidion occidentale* in true fir. To abate potential hazards, true fir with signs of root disease infection should be removed whenever a target (people or property) exists. To assess trees for root disease, it is reasonable to use the condition of the crown as an indicator of advanced decay. Although not always caused by root decay, a thin crown and/or short leader growth does indicate poor tree vigor. A tree with reduced photosynthesis is not able to maintain healthy roots as well as a tree with a full and healthy crown. In the presence of root disease, unhealthy roots will likely be overcome with decay faster than vigorously growing roots. For this reason, the thinner the crown of a tree in an area where root disease is confirmed, the more likely it is that the roots have been weakened by decay (see Appendix B – *H. annosus* hazard tree supplement).

Despite the effectiveness of any long or short-term plans to prevent tree injury and mortality, some trees, through declining health, will eventually become hazards to the public. To minimize the risks associated with hazard trees, they should be identified and removed before they fail. The current practice for many National Forest campgrounds and summer home tracts is to remove trees as they die. This eliminates the risk from dead trees but fails to address living trees that are infected with root disease, heart rot, and/or have a structural defect. These high-risk green trees are equally hazardous and should not be overlooked. Therefore, it is recommended that the Forest develop a hazard tree evaluation and monitoring plan for these recreation areas. At your request, Forest Health Protection can provide information and assist with the development of this plan (an R5 FHP Hazard Tree Guide will be available by spring 2011). In the short-term, trees within the campgrounds and summer home tracts that have obvious stem decay, dead tops and/or large dead branches should be carefully evaluated and hazards removed or pruned as soon as possible. All standing dead trees within striking distance of any target should be removed immediately.

Potential for FHP Funding

Forest Health Protection may be able to assist with funding for thinning and removing green material from overstocked areas within the Bucks Lake Project. Thinning projects in this area would meet the minimum requirements for Western Bark Beetle Program funding and are supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact me at 530-252-6431 or email dcluck@fs.fed.us.

/s/ Danny Cluck

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cc: Alex Yiu, Mt. Hough RD
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Appendix A – Hazard Tree Alert

Available on the FHP website: http://www.fs.fed.us/r5/spf/publications/ssssa/Hazard_Tree_Alert.pdf

USDA Forest Service, Forest Health Protection, Northeastern California Shared Services Area

Hazard Tree Alert

True firs that survived wildfires are failing in as little as three years

Black trees.....Be on the lookout for hazardous trees in burned forests. This kind of warning is common when conducting work in areas that have experienced wild or prescribed fires. Fire-killed trees are usually abundant and begin to fall about 3-5 years post-fire, creating very hazardous working conditions. Performing your job in these areas requires you to be extra cautious at a minimum, and under certain weather conditions such as wind, to stay out of areas entirely. Walking a wide path around existing snags is one way to reduce the odds of being struck should one fail.

Green trees.....But what about the surviving trees? Recent monitoring of fire-injured trees has revealed the failure of 8" to 24" dbh red and white fir, with green crowns, in as little as three years. The rate of failure increases dramatically after the fourth year post-fire, especially in conjunction with high winds or heavy snows.

During the 1999 Bucks Fire on the Plumas National Forest the crowns of many true firs were light to moderately scorched. However, these same trees suffered moderate to severe cambium injury and near complete girdling in some cases. Following the fire, frass and/or boring dust from wood boring and ambrosia beetles was evident on many of the tree boles, often indicative of internal injury. Bark sloughing over the last couple of years from the damaged areas of the bole and root collar has revealed extensive decay of the sapwood, however, most of these trees have maintained green crowns. During the fourth year post-fire, a few trees within the burn that had green crowns and extensive bole decay failed. In the fall of 2004, after an early storm brought heavy snow and wind, many more trees failed with these same characteristics. This has also been observed recently in a few fir trees in the 2001 Star Fire (Tahoe National Forest) and the 2000 Storrie Fire (Lassen National Forest). Based on the number of failed green trees observed this year in the Bucks Fire, true firs in these other fire areas are likely to start coming down at a higher rate within the next couple of years. People working in these areas or any other recently burned areas that contain red or white fir with similar fire injury, i.e. moderate to severe bole scorch with light to moderate crown scorch, should consider these trees hazardous until a closer inspection of the bole is completed. Forest Health Protection is currently working on fire-injured tree evaluation criteria to facilitate the early identification of trees that may succumb to the type of decay and failure presented here. For more information, contact Sheri Smith or Danny Cluck of the Forest Health Protection staff at 530-257-2151.

Extensive bole charring on this "live", 12" dbh red fir resulted in cambium kill and subsequent attack by ambrosia and wood boring beetles. Decay is now nearly 100% in pre-fire sapwood.

This 18" dbh red fir suffered >50% cambium kill during the 1999 Bucks Fire. It failed in the fall of 2004 with a full green crown.

This 8" dbh, fire-injured white fir was surviving with <5% of its functional xylem and phloem. The crown was still green when it failed in 2004.

Lat 39.88581 Lon -121.18592

Appendix B – *H. annousus* hazard tree supplement (Note: named now changed to *H. occidentale*)

ROADSIDE/FACILITY HAZARD TREE IDENTIFICATION GUIDELINES
for the Lassen, Plumas, Modoc and Tahoe National Forests

Update: July 2008

Forest Health Protection (FHP)
Northeastern CA Shared Services Area

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Supplement to the February 2008 guidelines for pockets of S-type annosus root disease (*Heterobasidion annosum*) in stands with true fir (white or red fir):

When evidence of S-type annosus root disease is present in an area, such as the presence of failed and uprooted green true fir trees (with roots exhibiting "delaminated" decay) (Figure 1) or conks present in old true fir stumps (Figure 2) or on decayed roots of recent blowdown, it is possible that many of the standing true fir in the immediate area are also infected and should be closely examined as potential hazards. When assessing individual true fir in these areas, it is reasonable to use the condition of the crown as an indicator of advanced decay. Although not always caused by root decay, a thin (declining) crown with a rounded top does indicate poor tree vigor. A tree with reduced photosynthesis is not able to maintain healthy roots as well as a tree with a full and healthy crown. In the presence of annosus root disease, unhealthy roots will likely be overcome with decay faster than vigorously growing roots. For this reason, the thinner the crown of a tree in an area **where annosus root disease is present**, the more likely it is that the roots have been weakened by decay.

Figure 1. Delaminated decay in roots of green blow down.

Figure 2. Annosus conks in stump.

Appendix C - Insect and Disease Information

Fir Engraver (*Scolytus ventralis*)

Hosts: True firs

Distribution in California: Throughout the range of true fir.

Identification: The fir engraver is a medium-sized bark beetle, measuring about 4 mm in length. It is the largest of the shiny black *Scolytus* beetles and is recognized by the concave abdomen typical of the genus. Trees under attack are not always easily recognized, although sometimes boring dust will be evident on the bark. Often, successfully infested trees cannot be differentiated from uninfested trees until the year after attack when their foliage begins to fade. Extensive pitch streaming from entrance holes, and sunken patches of bark, indicate unsuccessful attacks. The adult or egg gallery of the fir engraver is oriented perpendicular to the grain of the wood and larval galleries are parallel to the grain on both sides of the egg gallery. Both the egg and larval galleries deeply score the sapwood.

Effects: All sizes of trees can be attacked and killed by the fir engraver. As opportunists, these beetles often kill trees affected by root diseases or stressed by other insects such as the Douglas fir tussock moth. Sublethal attacks resulting in topkill and branch flagging are also common.

Ecological Role: The fir engraver is a key mortality agent for firs under stress. By killing trees, the fir engraver increases diversity in a stand and creates habitats for numerous organisms that depend on dead wood. Engravers also colonize down material and hasten its recycling by introducing wood decay fungi through the bark.

Life History: The fir engraver completes one generation per year in most locations. Two generations may be possible at lower latitudes and elevations. Adult beetles fly and initiate new attacks between June and September, with peak flight activity in July and August. Females initiate attacks and after mating, construct an egg gallery perpendicular to the grain of the tree. Eggs are laid on both sides of this gallery, and larvae hatch within two weeks. Winter is passed in the late larval or pupal stage, and young adults mature by the following summer.

Conducive Habitats: Fir engraver activity is most commonly associated with trees infected by root pathogens. Other stress agents such as defoliating insects can predispose trees to engraver attacks. Typically, fir engraver populations will peak one or two years after a defoliator outbreak subsides. Drought conditions are perhaps the most significant trigger for creating substantial amounts of fir engraver habitat. By far the most impressive fir engraver outbreaks have occurred on dry fir sites (characterized by less than 30” of annual precipitation) during periods of drought. The fir engraver is also associated with windthrows and logging slash, but unlike the pine engraver, does not commonly build populations that can subsequently invade standing trees.

Similar Insects: Other engraver beetles attack red and white fir, including the silver fir beetle, *Pseudohylesinus sericeus*, and other species of *Scolytus*. They may be separated by gallery patterns, depth of sapwood scoring and characteristics of adult beetles.

Management Strategies: Since the majority of endemic fir engraver populations are associated with root diseases, management of these disease pockets will also serve to manage the fir engraver. Stand thinning measures for fir stands on drier sites generally do not seem to yield the same benefits that are seen with pines. However, thinning does typically result in increased growth and vigor and in wetter areas

(areas with annual precipitation greater than 30 - 35”). Silvicultural practices aimed at maintaining healthy stand conditions appear to offer the best chance for minimizing engraver-caused mortality. Care should be taken during treatments to minimized tree injury and compaction as residual firs are easily damaged during harvest activities and are sensitive to soil compaction. These additional stresses can make them even more susceptible to fir engraver attacks after treatment than before. Large-scale outbreaks associated with drought conditions can best be managed by reducing the occurrence of the fir host on dry sites. Once an outbreak begins, sanitation/salvage appears to result in little or no population reduction of fir engravers.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.
Heterobasidion root disease in western North America is caused by two species:

Heterobasidion occidentale (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* („P“ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* („S“ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living

conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by Cronartium ribicola an obligate parasite that attacks 5-needled pines and several species of Ribes spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes spp., its spread from Ribes spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.